Statistical Models of Average Path Loss

Exercise 1: What is the free-space path loss, in dB, at 10 m for $f = 1500$ MHz? What is the value of $PL(1 \text{ km})$?

P_L is $\frac{1}{P_R}$ at $P_T = 1$ $G_T = G_R = 1$

"Gain" = $\frac{1}{\text{Loss}}$ (in dB: gain = −loss)

$$PL = \left(\frac{\lambda}{4\pi d}\right)^{-2}$$

$d = 10\,m$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{1.5 \times 10^9} = 0.2\,m$

$$= \left(\frac{0.2}{4\pi \cdot 10}\right)^{-2} =$$

```
d =  0.0090000
octave:4> pl=(0.2/(4*pi*10))^(-2)
pl =  394784.17604
octave:5> 10*log10(pl)
ans =  55.964
octave:6>
```

≈ 56dB path loss.

$$PL(d)_{\text{dB}} = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right)$$

say: $d_0 = 10\,m$.

$$= 56 + 10 \cdot 2 \cdot \log_{10}\left(\frac{1000}{10}\right)$$

$$= 56 + 20 \cdot 2$$

$$= 96 \text{ dB}.$$

$P_L = \frac{P_R}{P_T}$???

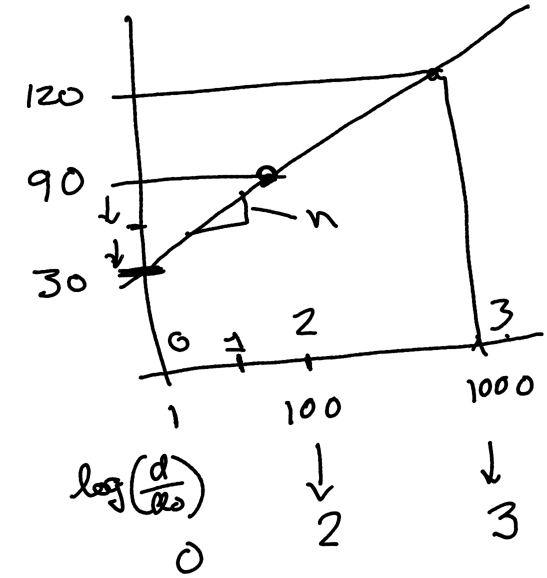
Exercise 2: If the path loss is 90 dB at 100 m and 120 dB at $d =$ 1 km, what are n and $PL(d_0 = 1\text{ m})$?

$$n = \frac{30}{1} = 10n$$

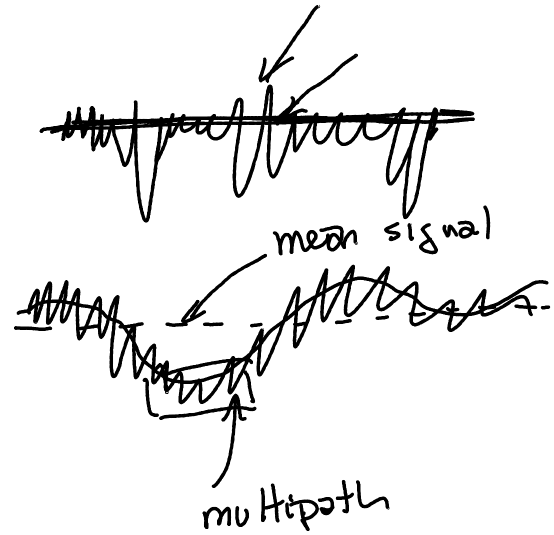
$$n = 3$$

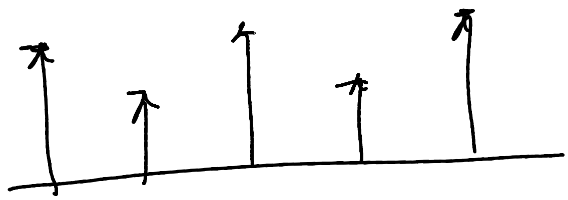
$$PL(d)_{\text{dB}} = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right)$$

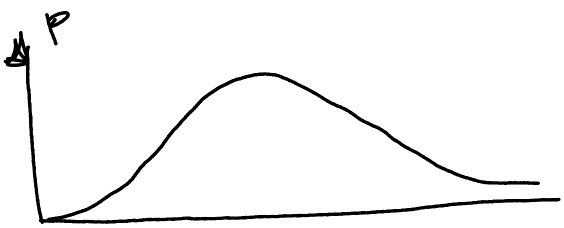
$$PL(1m) = 90 - 2 \cdot 30$$
$$= 30 \text{ dB}$$

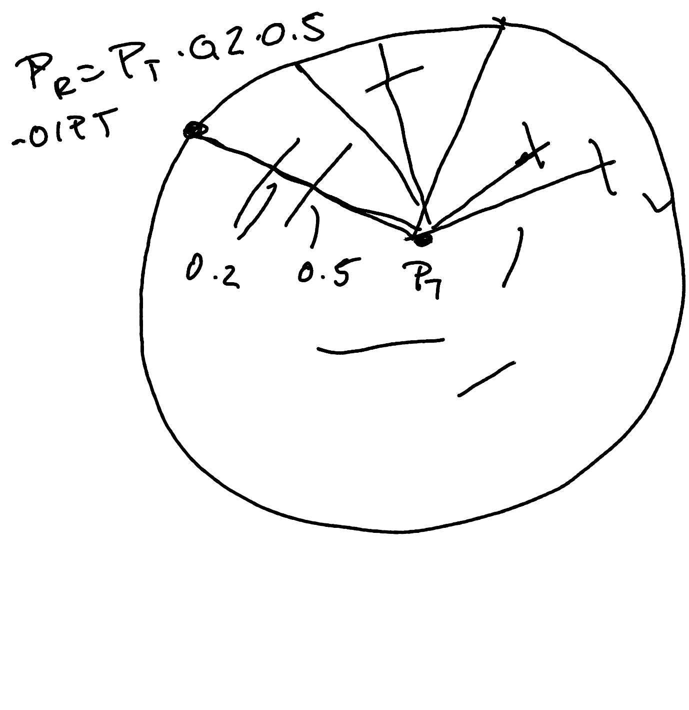


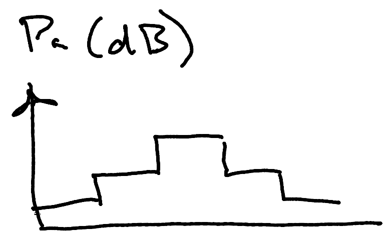
Exercise 3: What path would you have to travel if you wanted to measure the average path loss at a given distance from a particular transmitter?











Exercise 4: Compute the median path loss predicted by the Okumura-Hata model at $f = 900\text{MHz}$, base station and mobile antenna heights of 30m and 1m respectively, and a distance of 2km.

$$L_b = 69.55 + 26.16 \cdot \log \frac{f}{\text{MHz}} - 13.82 \cdot \log \frac{h_{Base}}{m} - a(h_{Mobile})$$
$$+ (44.9 - 6.55 \cdot \log \frac{h_{Base}}{m}) \cdot \log \frac{d}{km}$$

where:

$$a(h_{Mobile}) = (1.1 \cdot \log \frac{f}{\text{MHz}} - 0.7) \frac{h_{Mobile}}{m} - (1.56 \cdot \log \frac{f}{\text{MHz}} - 0.8)$$

The model is restricted to:

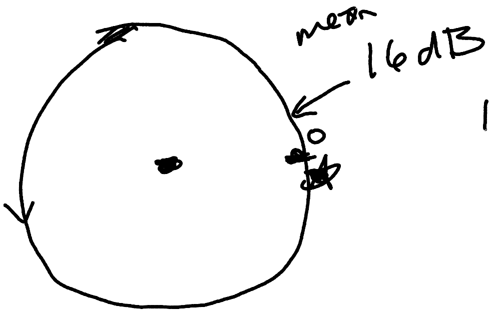
f:	150 ... 1000 MHz
h_{Base}:	30 ...200 m
h_{Mobile}:	1 ...10 m
d:	1 ...20 km

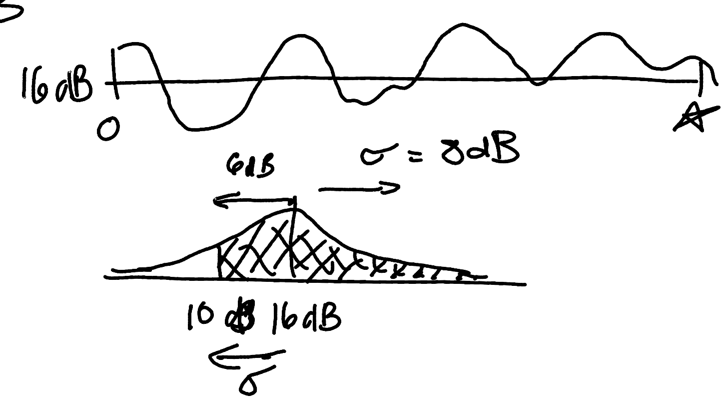
[1] "log" means "$\log_{10}$"

Exercise 4: Compute the median path loss predicted by the Okumura-Hata model at $f = 900\text{MHz}$, base station and mobile antenna heights of 30m and 1m respectively, and a distance of 2km.

```
octave:8> f=900
f =  900
octave:9> d=2
d =  2
octave:10> hb=30
hb =  30
octave:11> hm=1
hm =  1
octave:12> ah=(1.1*log10(f)-0.7)*hm - (1.56*log10(f)-0.8)
ah = -1.2590
octave:13> Lb=69.55+26.16*log10(f) - 13.82*log10(hb) - ah + (44.9-6.55*log10(hb))*log10(d)
Lb =  138.28
octave:14>
```

Exercise 5: A cellular system is designed so that users on the cell edge have an average SNR of 16 dB. The system requires that users have a minimum SNR of ~~8~~10dB to place a call. The standard deviation of the log-normal fading is 8dB. What fraction of users at the cell edge will be able to place calls?





$$\Pr[z > \gamma] = Q\left(\frac{\gamma - m}{\sigma}\right) = \frac{1}{2}\operatorname{erfc}\left(\frac{\gamma - m}{\sqrt{2}\sigma}\right)$$

$\gamma = 10$, $m = 16$, $\sigma = 8$ } dB

P(can make call) = 0.77